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# EXISTENCE THEORY AND CONTINUATION ANALYSIS OF NONLINEAR PANTOGRAPH EQUATIONS VIA HILFER-HADAMARD FRACTIONAL DERIVATIVE

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**Abstract.** In this manuscript, we study the existence theory and continuation analysis of nonlinear pantograph equations via Hilfer-Hadamard fractional derivative. We initially establish new local existence theorems. Then, we extended the continuation theorems. Some global existence results are constructed based on continuation theorems.

**Keywords.** Nonlinear pantograph equation, Hilfer-Hadamard fractional derivative, Existence, Fixed point, Continuation.

**AMS (MOS) subject classification:** 26A33, 34K40, 34K14.

## 1 Introduction

Fractional differential equations (FDEs) are appeared in mathematical modeling of processes in science and engineering. Hence the theory of FDEs is an area intensively developed during last decades. The monographs of Hilfer[9], Kilbas [12], Miller [14] and Abbas [2], include a study of techniques of solving which are an extension of procedures from differential equations theory. Recently, considerable attention has been given to the Hilfer fractional derivative which was introduced by [9]. The numerous results on existence and uniqueness of solution of FDEs with Hilfer and Hilfer-Hadamard fractional derivative are studied in [1, 3, 4, 7, 10, 15] by different methods.

Functional differential equations with proportional delays are usually referred to as pantograph equations. These equations arise in rather different fields of pure and applied mathematics, such as electrodynamics, control systems, number theory, probability, and quantum mechanics. Therefore, the problems have attracted a great deal of attention, one can refer to [16, 17, 18, 19]. Kou et al.[11], considered Riemann-Liouville type FDEs and developed sufficient conditions devoted to the continuation theorems and existence of solutions. Later, Li and Sarwar studied existence and continuation